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TECHNICAL PROBLEMS ASSOCIATED WITH COMMERCIAL COMMUNICATION SATELLITES

Part E: Economic Aspects of Satellite Communication Systems

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I INTRODUCTION

The volume of overseas telecommunications has increased rapidly since the introduction of submarine telephone cables. If this rapid growth continues, cables might prove inadequate to meet the demand for overseas communication services. The development of communication satellites presents an alternative means for meeting possible future requirements. The technical feasibility of both the random-orbit medium-altitude satellite and the synchronous stationary-orbit satellite has been demonstrated. The choice between systems based on these two types of satellites will be made on the basis of technical advantages and economic feasibility.

The purpose of this section of the Final Report on Contract NASr-49(08) is to examine the economic feasibility of communication satellites. This examination rests largely on a survey of the available literature. New approaches to the problem have not been developed during this study. It has been possible, however, to draw some conclusions:

(1) No accurate method for forecasting overseas telecommunication traffic exists at this time. All estimates that have been made should be viewed as points within a fairly large range of values.

(2) A period of several years will elapse from the initial operational date of a satellite communication system until the system becomes profitable. Thus, in addition to the initial system cost, funding must be provided to carry the system through that period when expenses will outrun revenues.

(3) Ultimate preference on economic grounds will be accorded the system utilizing synchronous-orbit satellites, despite the probability that a random-orbit system will be less expensive initially.

(4) The key to system costs is reliability as expressed by the probability of a successful launch and by the mean time to failure. Reliability is also the prime determinant of how long the system will be unprofitable and of when the synchronous-orbit system will become cheaper than the random-orbit system.

(5) Voice communications will take up the bulk of overseas circuits (between 80 and 95 percent) for at least the next decade. This stems from the fact that voice messages require greater bandwidth than telegraph, Telex, or Datalex messages and also present more severe peaking problems (a lower circuit utilization factor).

(6) Television is unlikely to be a major factor in the demand for overseas communication circuits, because of differences in time zones and competition from video tape which can be delivered rapidly by commercial jet aircraft.

(7) If the proposed 720-voice-channel transistorized cable is laid across the North Atlantic, ultimate profitability of a satellite communication system would be delayed, and the early regional system proposed by some analysts would be considerably less attractive commercially. On December 10, 1963 it was announced by AT&T that it did not intend to lay such a cable.

II TRAFFIC FORECASTS

Three general methods have been used in forecasting telecommunication traffic:

(1) Extrapolation of trends in data on such traffic

(2) Tying traffic to general economic indicators, such as foreign trade or gross national product, which must also be forecast

(3) Tying traffic to variables within the telecommunication industry itself, such as the number of telephones or the telephone density (number of telephones per hundred persons), which can be predicted with a high degree of confidence.

Most traffic forecasts have been based on some combination of the above methods rather than on a single method. Several forecasts are summarized in Table I. These estimates vary widely in both the estimated demand for overseas telecommunication channels and the annual growth rates in such demand. The projected need for channels varies from 578 to 7,600 for 1970 and from 1,230 to 28,000 for 1980—a ratio of more than ten to one between the maximum and minimum estimates. Projected annual rates of growth show a variation between 7.5 and 25 percent—a reflection of the basic assumptions and methods incorporated in the estimates. A brief discussion of each of the eight estimates in Table I follows.

A. AMERICAN TELEPHONE AND TELEGRAPH COMPANY

This estimate, presented before the Federal Communications Commission early in 1961, projects growth at a 20-percent rate.[1*] The basis for the projected rate of growth is not specified. The requirements given for 1980 include about 2,000 voice channels for television. All other estimates, unless based on the AT&T statement, exclude possible requirements for overseas television.

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* References are given at the end of this part of the report.

Table I

ESTIMATED DEMAND FOR OVERSEAS TELECOMMUNICATION CHANNELS

SOURCE	NUMBER OF EQUIVALENT VOICE CHANNELS	YEAR	ANNUAL GROWTH RATE (voice channels*)	METHOD OF ESTIMATION	COMMENTS
AT&T	2,250 14,000	1970 1980	20%	Unknown	1980 requirements include U.S. traffic to Cuba and Bahamas. 10,000 channels for voice, 2,000 for data, and 2,000 for television
Ad Hoc Committee	3,800 14,000	1970 1980	Rapid growth through 1970 14% after 1970	Unknown, but 1970-1980 growth rate reflects historic growth since 1956.	Same as AT&T estimates except for assumption of reduced rates between 1965 and 1970
Booz, Allen & Hamilton	1,900 (425-1,000 via satellites) 7,500 (5,500-6,275 via satellites)	1970 1980	14.9%	Analysis and extension of market trends for voice, telegraph, Telex, Datalex; comparison with trends in selected economic indicators	Based on traffic to and from the U.S. and Western Europe; excludes U.S. to Cuba and Bahamas, television, and broadband data. Range of traffic via satellites reflects varying assumptions on deepwater cables
J.W.A. Buyers	4,800 (2,100 via satellites) 17,000 (14,000 via satellites)	1970 1980	25% through 1970 14% 1970-1980	Analysis and extension of market trends	World traffic excluding short hauls † Assumption of significantly reduced rates. Only study including 720-channel cable proposed for North Atlantic
General Electric	578-1,637 1,230-8,272	1970 1980	7.8%-17.6%	Minimum estimates by "operation research" approach, assigning weights to various factors; maximum estimates by extension of trends with geographic allocation proportionate to minimum estimates	World traffic excluding short hauls †
R.I. Hart	952 1,897	1970 1980	7.5%	Traffic between countries projected by relationships among such telecommunications parameters as message volume, number of telephones, telephone density, etc.	Voice traffic only for messages to and from British Commonwealth, plus traffic between U.S. and Western Europe
RAND Corporation	Not given		22% annual growth in revenues 1960-1965; 11.5% growth in revenues 1965-1975	1960-1965, analysis of markets, including military requirements, assuming rate reduction; 1965-1975, comparison with growth rates for similar industries	Growth of revenues with assumption of reduced rates implies somewhat higher rate of growth in number of channels.
RCA	3,800 U.S. traffic 7,600 world traffic 14,000 U.S. traffic 28,000 world traffic	1970 1980	Same as Ad Hoc Committee	Assumes Ad Hoc Committee estimates for U.S. traffic only; world traffic derived by ratio of worldwide ocean-borne trade to U.S. ocean-borne trade.	Implicit assumption that telecommunications traffic will be the same regardless of rates

* Unless otherwise specified

† Examples of short hauls: U.S. to Cuba and France to North Africa.

B. AD HOC CARRIER COMMITTEE

The projected demand for telecommunications prepared by the Ad Hoc Carrier Committee[2] is a modification of the AT&T estimate.[1] A rapid period of growth is foreseen through 1970, largely in response to proposed reductions in rates charged to users of overseas communication facilities. Growth in demand for the 1970s is extrapolated on the historic growth rate of 14 percent.

C. BOOZ, ALLEN & HAMILTON

Telecommunication demand projections in the study of Booz, Allen & Hamilton[3] include all intercontinental traffic in which either North America or Europe is involved; this represents about 90 percent of the world traffic. Trends for each type of traffic—voice, telegraph, and data—were analyzed and used as a basis for projecting the number of overseas messages. Message traffic was converted to channel requirements on the basis of certain assumptions with respect to peak loads and to the ratio of circuit time to revenue producing time. Reference is made to correlations between message traffic and such economic indicators as gross national product (GNP), the volume of international trade, and long-term direct investment overseas, but apparently, no use was made of these indicators in projecting message traffic. A comparison of trends is included to test the reasonableness of the message traffic projections.

D. J. W. A. BUYERS

The study submitted by J. W. A. Buyers as a Master's thesis at the Massachusetts Institute of Technology[4] includes projections of world-wide demand for overseas telecommunication channels. Trends for various types of traffic are examined as in the Booz, Allen and Hamilton study. Emphasis is placed on channel routes from 2,000 to 3,000 miles long. It is proposed that a single rate be charged to all users of communication satellites. The very high rates of growth in demand through 1970 (about 25 percent per year) are based on combined assumptions of rate reductions and aggressive market promotion. This is the only study including a proposed 720-channel cable across the North Atlantic in the count of overseas channels provided by cable. (See Sec. VI).

E. GENERAL ELECTRIC COMPANY

Two sets of estimates for world-wide demand for telecommunication channels are provided in the study prepared by the General Electric Company.[5] The first set of estimates was derived through a weight-ranking system including fourteen factors. Among these factors are population, income, trade, number of telephones, political and military factors, time differences, and language. This approach yielded a minimum set of projections and also a geographic distribution of demand. The second set of estimates, the maximum projections, was derived by extending current communication growth rates; the resulting totals were then distributed geographically in the same ratios as in the minimum set of estimates. It is interesting to note that for 1970 the volume of communication traffic between South America and Africa is projected to be 15 percent of that between North America and Western Europe although in 1960 the traffic between South America and Africa was less than 0.1 percent of that between North America and Western Europe. (See Table II.)

F. R. I. HART

Communication requirements were projected by R. I. Hart[6] for voice traffic for the British Commonwealth and for telephone traffic between Western Europe and the United States. This is the only study reviewed in which estimates were based solely on relationships among telecommunication parameters. Traffic between any two areas was found to be closely correlated with the product of the number of telephones in those areas; the number of telephones was predicted on the basis of population and of a telephone density function. The annual growth rate in telecommunication demand is the lowest given in the reports reviewed.

G. THE RAND CORPORATION

In a report prepared by the RAND Corporation,[7] the projections for world-wide overseas communications are stated in terms of revenue from such traffic rather than in terms of message units or channels required. Estimates for 1965 were prepared through a detailed analysis of various markets, including military demand. Revenues for 1970 and 1975 were estimated on the basis of a "normal" growth of 11.5 percent per year.

Table II

ESTIMATED OVERSEAS TELEPHONE MESSAGE TRAFFIC, 1960
(Thousands of Two-Way Messages)

AREA	NORTH AND CENTRAL AMERICA	SOUTH AMERICA	EUROPE	AFRICA	MIDDLE EAST AND SOUTHERN ASIA	NORTHERN ASIA	OCEANIA	ALASKA AND HAWAII	TOTAL
North and Central America	--	252	1,140	9.2	30	141	41	918*	2,530
South America			34	0.3	0.4	0.8	1.2	†	37
Europe			--	170.0	110	16	47	1.2	344
Africa				--	9.5	12	6.5	†	28
Middle East and Southern Asia					42	49	4.7	†	96
Northern Asia						108	8.3	3.6	120
Oceania							35	2.8	38
Alaska and Hawaii								1.1	1
Total	--	252	1,174	179	192	327	144	926	3,194

SOURCE: AT&T, "Estimated Overseas Telephone Message Traffic, 1960" (October 1961) (mimeographed).

* Hawaii—North America, 509,000 messages; Alaska—North America 408,000 messages.

† Less than 0.1.

NOTES: (1) The table is arranged in triangular form to eliminate duplication of messages in the various cells of the table, so that the sum of column totals and that of line totals each equals world wide overseas messages.

(2) Traffic is omitted on short routes such as U.S.-Cuba, France-North Africa, and United Kingdom-Western Europe.

(3) Items in diagonal cells represent message traffic between countries within an area such as Indonesia-Thailand, Japan-Hong Kong, Australia-New Zealand, and Hawaii-Alaska.

(4) Total traffic originating or terminating for an area, equals the sum of the column total and the line total for that area except where traffic within an area is included. In these cases such traffic should besubtracted from either the column or line total to avoid double-counting.

(5) Items may not add to totals due to rounding errors.

A somewhat higher growth rate for the number of channels is indicated by probable reductions in revenue per unit of capacity. This is the only report among those reviewed giving estimates of the military demand for communication facilities.

H. RADIO CORPORATION OF AMERICA

The projections of world traffic and communication channels in a report from the Radio Corporation of America[8] were based on the growth rates used in the Ad Hoc Committee study.[2] The authors assumed, however, that the Ad Hoc Committee projections cover traffic only to and from the United States. Total world traffic and channel requirements were derived by applying the ratio of world-wide ocean-borne trade to United States ocean-borne trade to the volume of U.S. overseas telecommunications to derive world-wide telecommunication volume. This method followed a suggestion made by J. R. Brinkley.[9] The projections of the number of channels required to handle world traffic are the highest found in any study.

III EVALUATION OF TRAFFIC FORECASTS

The wide variation in projected telecommunication traffic and channel requirements stems not only from different data bases but also from different methods of estimation. To choose the more reasonable among these forecasts, an evaluation of the methods underlying them is necessary. It will be argued in this section that no close relationship between telecommunication traffic and such general economic indicators as GNP or foreign merchandise trade has yet been convincingly demonstrated. Each of the other basic methods of projection—extrapolation of trends in traffic and use of relationships among telecommunication variables—has severe limitations. The use of an approach that includes a detailed analysis of the various markets for telecommunication services (that used by the RAND Corporation,[7] Booz, Allen & Hamilton,[3] and J. W. A. Buyers[4]) is recommended. This approach necessarily involves a considerable element of judgment on the part of the analyst.

The use of correlations between overseas telecommunication traffic and economic indicators has often been suggested as a means for projecting communication traffic. The number of overseas calls to and from the United States is plotted against GNP, the value of exports and imports, and long-term direct foreign investment in Figs. 1, 2, and 3, respectively. For the period since World War II, correlation exists between overseas calls and each of these series. The first two series do not show a very large coefficient of determination (R^2), and a break in the apparent relationship between overseas calls and GNP or exports and imports occurs after 1957. Thus, if the relationships that existed through 1957 had been used to predict traffic for 1958 and 1959, the predicted values would have been substantially below the actual values.

Since 1957 economic growth in the United States has proceeded at a slower pace than during the postwar years 1947-1957, but a parallel break in the growth pattern of overseas communication traffic has not occurred. A lack of parallel growth patterns between GNP and individual industries has much historical precedent. The motion picture, radio broadcasting, and phonograph record industries achieved rapid growth during the depression of the 1930s. In each of these cases, the industry was

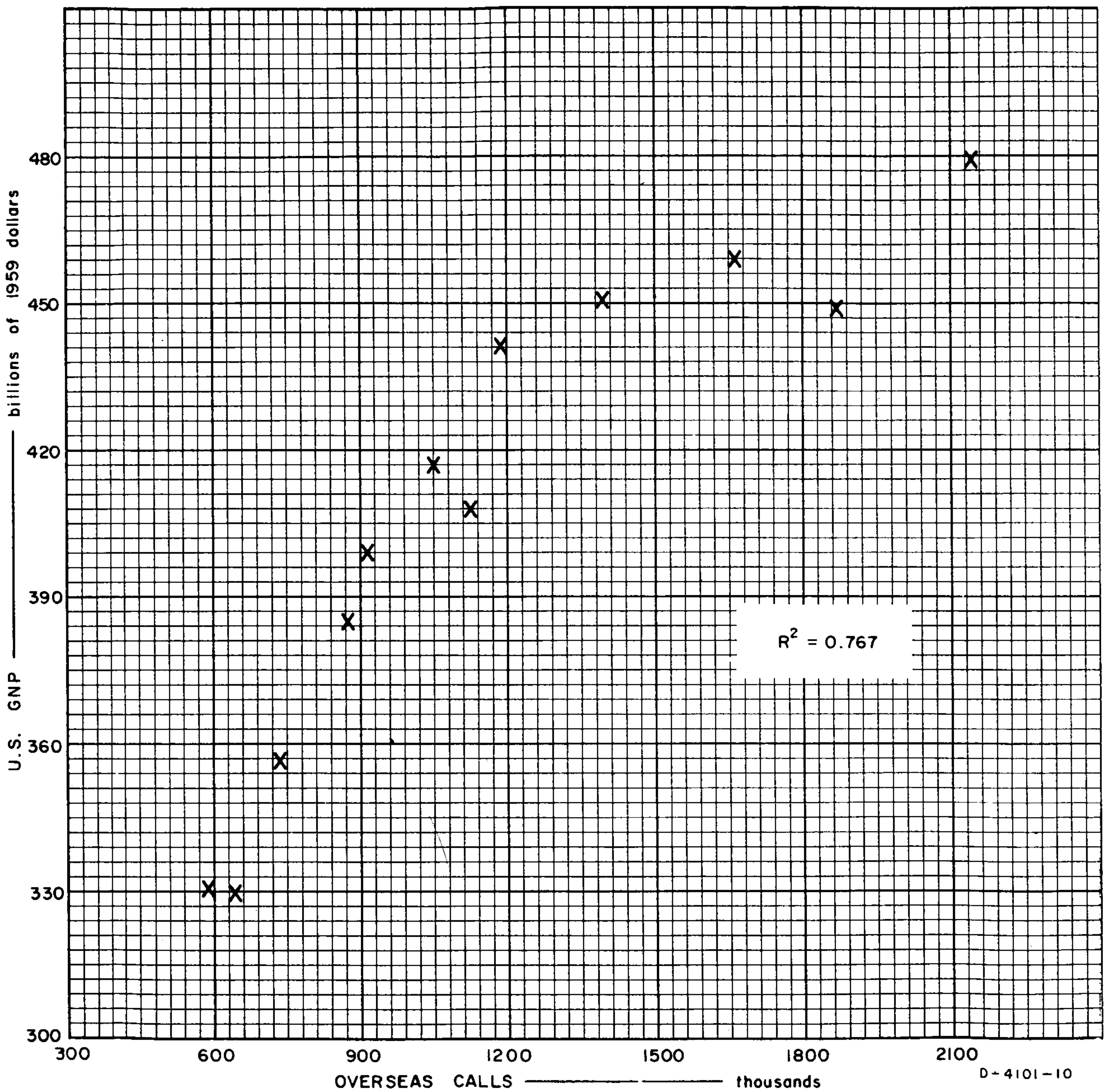

FIG. 1 OVERSEAS CALLS TO AND FROM U.S. VERSUS U.S. GNP

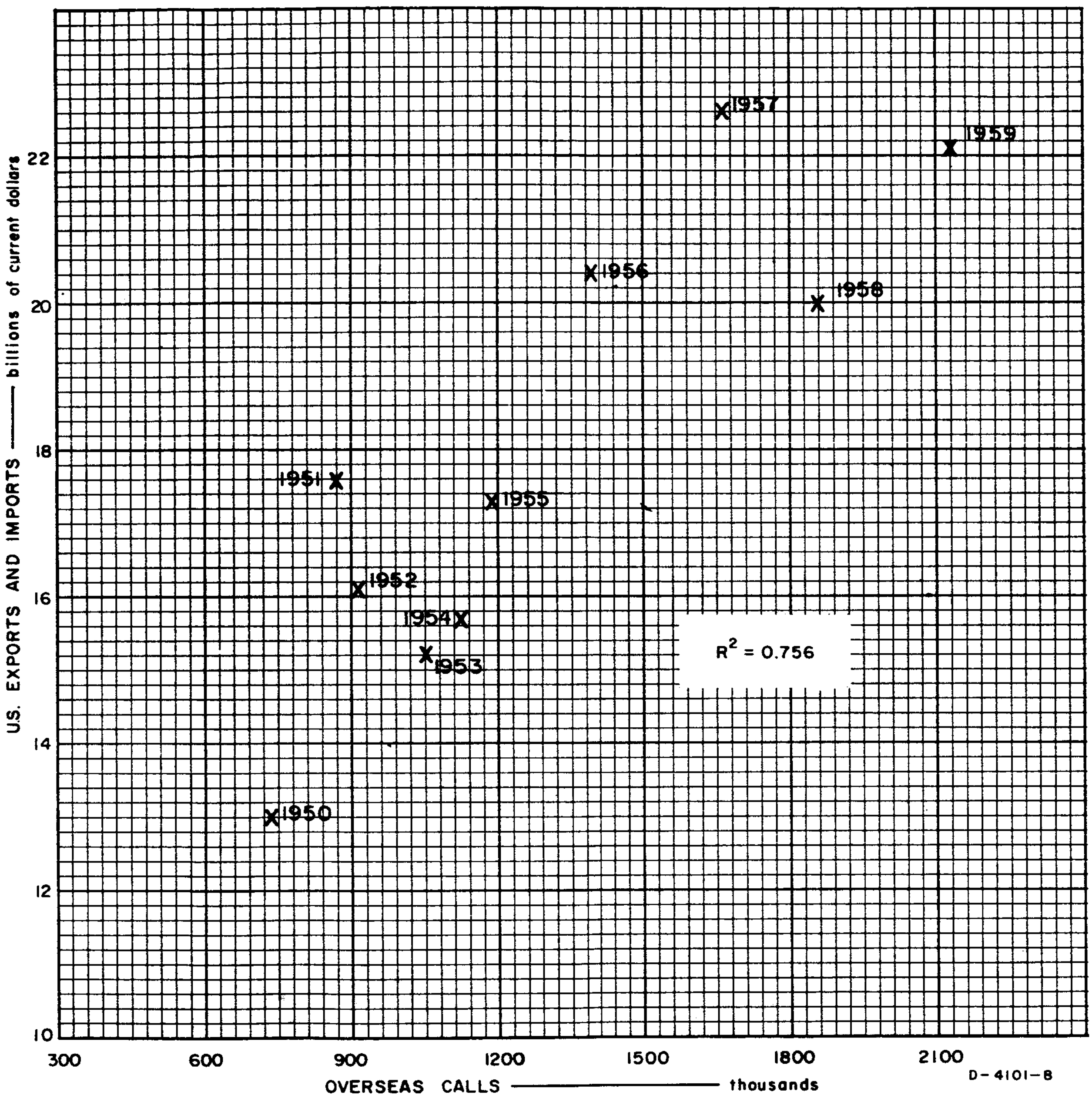

FIG. 2 OVERSEAS CALLS TO AND FROM U.S. VERSUS U.S. EXPORTS AND IMPORTS

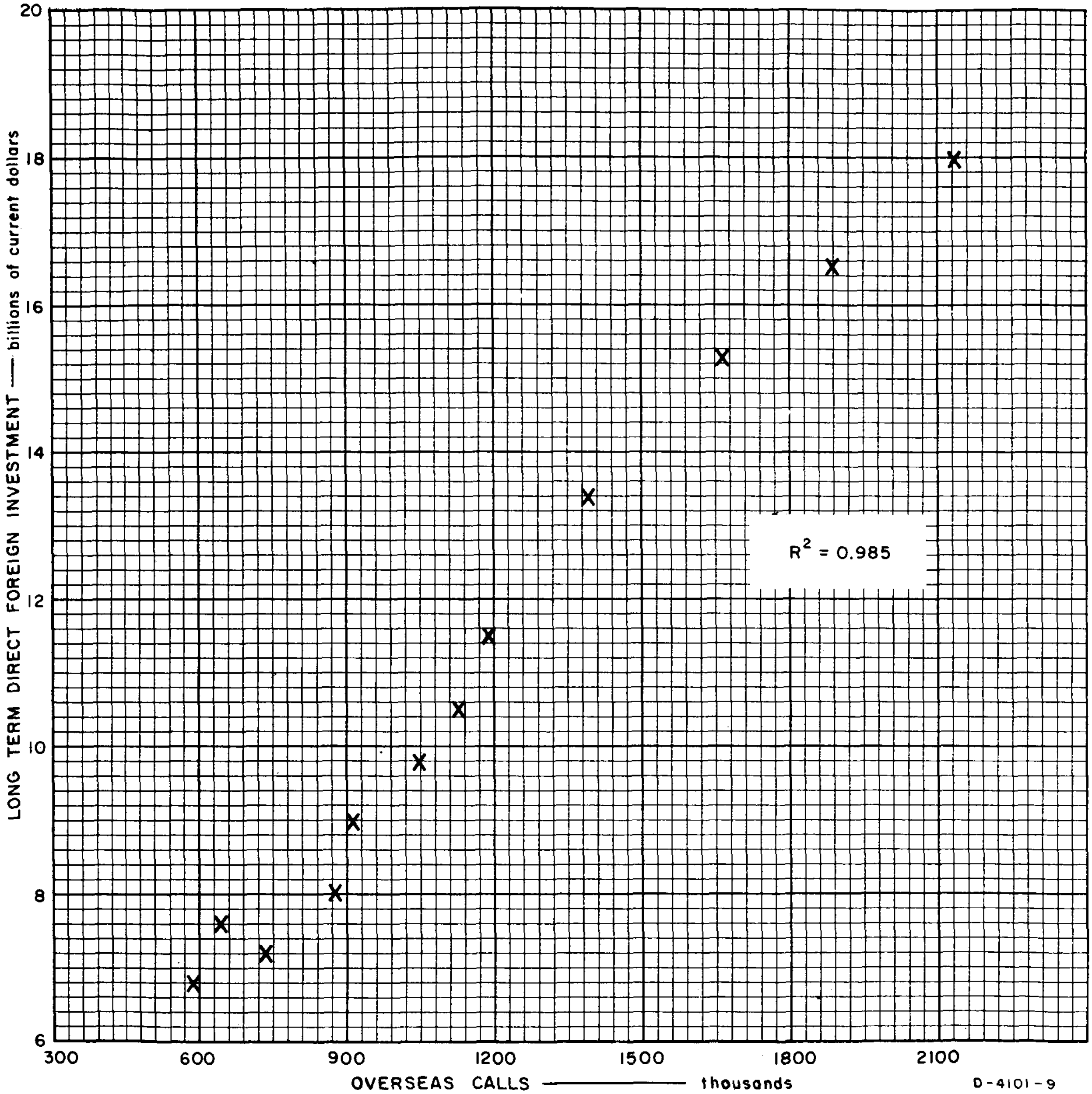

FIG. 3 OVERSEAS CALLS TO AND FROM U.S. VERSUS LONG-TERM DIRECT FOREIGN INVESTMENT

a relatively new one or had recently achieved significant technical advances. The overseas communication industry has recently experienced significant technical advance with the introduction of deepwater cables that provide much higher quality transmission than HF radio. The provision of this new service has already led to a rapid expansion of communications traffic between North America and Europe; and the extension of this service to other areas may be expected to increase traffic volume. Although growth in the use of new or improved products or services is more easily achieved and sustained in an environment of economic prosperity, growth in GNP has not always been a necessary condition for growth in new products and services.

The fact that at least 80 percent of intercontinental calls are originated by business has suggested to some analysts that the volume of communications may be correlated with overseas trade. It has been further suggested by J. R. Brinkley[9] that such trade can be used to assess the potential demand for overseas communications. From the data on overseas telephone calls and trade for the United States plotted on Fig. 2, a correlation similar to that noted for GNP can be seen, but apparently there has been a shift in the relationship between the two variables since 1957. Since economists have long noted a high correlation between movements in GNP and in merchandise trade, the remarks on correlation between message volume and GNP can be applied to message volume and overseas trade.

The assertion that trade patterns can be used to measure potential overseas communication demand depends upon the assumption that some "normal" ratio exists between telephone calls and trade. Nothing in this approach to the problem indicates when such a normal relationship occurs. The wide differences among trade-telephone call ratios are exemplified by trade and call volume between South America and Europe and between North America and Europe. (Table II). In 1960 the volume of calls between South America and Europe was only 3 percent of that between North America and Europe, while the volume of trade between South America and Europe was 45 percent as large as that between North America and Europe. Thus, to have achieved the same relationship between calls as between trade, the volume of calls between South America and Europe would have had to be fifteen times as large as it was. The achievement of a "normal" trade-telephone call ratio by 1970 (as postulated in RCA's estimates of communication traffic[8]) would imply growth rates in communication traffic ranging from 40 to 100 percent along some routes.

There are valid reasons why trade-telephone call ratios vary widely at present and why large variation should be expected to continue. First, there is great diversity in the commodities on which merchandise trade is based. These range from such staple items as wheat and crude oil to such complex ones as electric generators and electronic equipment. It is likely that less communication will be involved to arrange for a shipment of wheat, for example, than for a shipment of equal value of electric generators, with all their technical specifications. Thus, between nations whose trade largely involves manufactured goods, a higher trade-telephone call ratio can be expected than between nations whose trade is more oriented toward the exchange of raw materials.

The second reason why trade-telephone call ratios should vary is the fact that the volume of merchanidse trade reflects only a part of the economic or business relationships among countries. The United States, which has a surplus in its balance of trade, has had a negative balance of payments for the past few years. This results in part from movements of short-term capital abroad and from investment in foreign securities. Many transactions such as speculation in currencies and securities are not included in data on merchandise trade—and it is precisely such items that may require rapid, reliable communications. The same international financial centers where such speculation occurs also provide much of the financing of international trade. Since the primary international financial centers are in the United States and Western Europe, it is not surprising that the trade-telephone call ratio is higher between Europe and North America than that between any other pair of continents. There is no reason to believe that the primacy of these financial centers will be significantly altered over the next decade or two.

A final reason for rejecting trade-telephone call ratios as a reliable means for projecting overseas communication traffic and its geographic distribution is that predictions of the volume and geographic patterns of international trade include an element of considerable uncertainty. Trade between South America and Europe may be significantly affected by future decisions on tariffs and trade restrictions effected by the Common Market countries.

The use of the value of overseas long-term direct investment in explaining overseas message volume has been suggested for the same reasons advanced in the case of international trade. The data plotted in Fig. 3 show a very high correlation between overseas telephone calls and long-term direct investment abroad by the United States since World War II. This correlation may, however, be a spurious one, not an accurate reflection of underlying causation, for the following reasons. Such strong correlation did not exist for the period 1929-1939, when long-term direct investment abroad did not grow (and even declined during some years) but overseas communications showed some growth. The volume of overseas calls has not followed the geographic distribution of investments abroad. Through 1959, direct investment in South America exceeded that in Europe. Finally, the data on overseas calls include those between Hawaii and the continental United States while no data are available on the volume of investment made by residents of the mainland in Hawaii. Exclusion of calls between Hawaii and the mainland does, in fact, weaken the correlation observed above. (A similar comment applies to trade-telephone call ratios since data are lacking on trade between Hawaii and the mainland.)

Those who have suggested the use of economic indicators as an aid in projecting overseas communications have pointed out the limitations in the data on overseas communications. These include differences in reporting among countries, the difficulty in segregating traffic via a country from traffic terminating or originating in that country, and absence of data or reports for some countries. The limitations of economic data, however, are at least as severe. Measurement of GNP, international trade, and long-term direct investment abroad includes in each case a number of estimates, and data published one year are often subject to revision for several years. The data for United States long-term direct investment abroad initially published for 1957 were subsequently changed as the result of a census survey; the value of investments in South America, for example, was reduced by more than 10 percent. The size of GNP or national wealth and its relationship to overseas communications should logically include income or wealth for nations at both ends of a communication route. International comparisons or compilations of income or wealth are limited by differences in methods of accounting and estimation used to arrive at such quantities. Even when these differences are eliminated, it is still not possible to add or compare GNP for two countries in an unbiased manner. This stems from the need to base such comparisons on a common denominator or currency. Since the relative prices and quantities of goods and services which constitute GNP vary widely among nations, no single measure can fully account for these differences. The quantities of goods and services can be evaluated in terms of prices prevailing in either of the countries; the resulting combined GNP will differ according to which country's prices are used. This is known among economists as "the index number problem" which arises whenever international comparisons of income are made and introduces in them an inherent element of bias. Such bias is not present in the measurement of overseas communication traffic.

A method using only telecommunication parameters (message volume, number of telephones, and telephone density) to project overseas voice traffic has been suggested by R. I. Hart[6] (see Table I). High correlations were found to exist between voice traffic and the product of the number of telephones between pairs of countries, and the number of telephones was found to follow a telephone density function closely. The correlations, however, were computed for data that extended over only 5- to 10-year periods. Such correlations may not continue with the improvement of communication media; it is relevant to recall the significant growth in communications traffic following the laying of the first deepwater cables. Further, there is no provision in this method of projection for incorporating military demand for communication channels. It has been estimated that such demand will require 20 percent or more of the overseas cable channels by 1965.[7]

A method that combines economic indicators and telecommunication parameters to project overseas channels has been used by the General Electric Company.[5] The approach is an "operations research" procedure which includes a weight ranking of fourteen factors to derive the number of telecommunication channels required between pairs of continents. In the projection for 1970, it is estimated that between South America and Africa 15 percent as many channels will be required as between Europe and North America. Telephone message traffic between South America and Africa, however, was virtually nonexistent in 1960. It would be difficult to explain why this traffic should increase so significantly in relation to that across the North Atlantic. Apparently the weight-ranking method used resulted in an inflated estimate of African-South American requirements through the factors of population, income, and the number of telephones. Other factors such as common language, political and military ties, and trade and economic ties are conspicuous for their absence; the lack of economic relationships should be of primary importance in assessing the need for communication channels between the two continents. Since at least 80 percent of overseas calls are concerned with business, an estimated demand for a significant number of channels between two continents that have only insignificant business relationships is difficult to support. The economics of the two continents produce a very similar array of basic commodities that enter international trade. The relationship is one of competing for markets in the highly developed nations rather than one of exchanging goods and services. Since such basic relationships in the international economic sphere change only over long periods of time, no significant communications can be expected to arise within the next decade or more.

The method for projecting telecommunication requirements that appears best at this time is the one used by the RAND Corporation.[7] This approach includes an analysis of plans for laying deepwater cables through 1965, with an estimate of which markets will utilize overseas communications media. The probable military demand for communications channels has been extensively analyzed. The demand for communications after 1965 is expressed in terms of probable growth in revenues; a growth rate of 11.5 percent per year is used as a rate characteristic of a rapid growth service and as an approximation of recent experience. Although a considerable element of judgment is necessarily involved in such an analysis, this approach does take into account factors not specifically treated in other studies, such as military demand and the effect on demand of the provision of new services (a justification for a rapid growth rate of 22 percent annually through 1965).

IV PROJECTION OF DEMAND AND THE POTENTIAL MARKET FOR COMMUNICATIONS SATELLITES

Since the RAND Corporation study[7] states the demand for overseas telecommunications after 1965 in terms of revenue growth, the problem is to convert the revenue estimates into estimates of the number of channels required. Advances in deepwater cable technology continue to show promise of significant reduction in costs per channel-mile. This, together with a history of rate reductions, indicates that prices for overseas telecommunication services will probably decrease after 1965. Since utilization of communication media has been sensitive to price reductions in the past,[10] it is reasonable to expect a somewhat higher rate of growth in the number of channels than in total revenues. How much higher this rate of growth will be depends on the responsiveness of demand to price reductions (the elasticity of demand), a factor that is difficult to estimate and cannot be computed from the available data. An annual growth of 14 percent appears reasonable for channel demand, with an 11.5-percent annual growth in revenues. A somewhat higher or lower growth rate for telecommunication channels might be estimated, but the 14-percent rate is believed to be reasonable.

The overseas communication routes that will provide a market for communication satellites are those at least 2,000 miles long. By 1965 approximately 1,100 equivalent voice channels will be provided by deepwater cables along such routes.[11] A growth rate of 14 percent in the number of channels would imply the following total requirements:

YEAR	NUMBER OF CHANNELS
1970	1,950
1975	3,750
1980	7,250

A potential market for communication satellites can be represented by the difference between the estimates above and the number of channels provided by deepwater cables in 1965—a potential of 850 channels by 1970, 2,650 by 1975, and 6,150 by 1980.

Total revenues from overseas telecommunications, following the RAND Corporation estimates,[7] would be \$350 million in 1970, \$620 million in 1975, and \$1,070 million in 1980. If these revenues are allocated in proportion to the number of channels between cables and satellites, the following may be considered potential revenues for a satellite communications system:

YEAR	POTENTIAL REVENUES (MILLIONS OF DOLLARS)
1970	\$150
1975	440
1980	910

These estimates of overseas channels and revenues are, of course, subject to much uncertainty. Annual growth rates in the number of channels or in revenues 2 or 3 percentage points higher or lower than those estimated could easily occur. The estimated number of telecommunication channels and revenues for 1970, should, therefore, be considered as a point within a range extending about 20 percent above and below the estimates. The projections for years beyond 1970 would be surrounded by even wider confidence limits.

V THE COMPOSITION OF DEMAND FOR TELECOMMUNICATIONS SERVICES

Overseas telecommunication facilities are utilized by the military, lessees of circuits, and purchasers of message service. This third class of users originates the message traffic that statistics on overseas communications most commonly cover. The military agencies have historically provided the bulk of the telecommunication facilities they use. Military communication requirements have been growing, however, and at the same time a shift from military owned to privately owned communication media has been occurring. Military requirements have been a prime factor in determining when and where deepwater cables have been placed in service. The RAND Corporation study[7] includes a projection that at least 20 percent of the overseas channels in 1965 will be leased by the military. Projections of overseas communications beyond 1965 are based in part on the assumption that the growth in military demand will about keep pace with over-all growth in telecommunication demand.

Lessees of circuits include individuals, businesses, and telegraph and Datalex carriers. Individual lessees of voice circuits provided less than one percent of the demand for leased overseas circuits in 1961 and can be expected to be a very minor factor in total demand for some years.

Telegraph carriers completed a world-wide system of underseas telegraph cables by the beginning of this century. These carriers, however, are now in the process of abandoning these facilities in favor of lines leased on deepwater telephone cables. It is estimated that by 1965 all but an insignificant portion of overseas telegraph traffic will be carried via leased telephone circuits.

Telegraph and Datalex messages require far fewer circuits than do voice messages. Such record message traffic can obtain 22 record channels per voice channel. In addition, peaking is less severe with record traffic than with voice traffic, so a voice channel can carry a volume of record traffic even greater than that indicated by the 22:1 ratio of record to voice channels.

There are about twelve times as many overseas telegraph messages as overseas telephone calls. Intercontinental telegraph traffic has been growing much more slowly than overseas telephone traffic. (Between Europe and areas other than the United States, telegraph traffic has declined in recent years.) Datalex and Telex services have been provided between continents only very recently, so rapid growth in use of such services can be expected to level off soon to a growth rate comparable to that for overseas telephone messages. A major portion of overseas telecommunication circuits not leased by the military will be required to carry voice message traffic. All the studies that were reviewed include projections that from 80 to 95 percent of the overseas circuit requirements will carry voice traffic. Thus the key to estimating nonmilitary overseas circuit requirements is the probable growth in overseas voice message traffic.

Two potential markets which have not been considered up to this point are those for broadband data transmission and for television. The overseas channels leased by military agencies can be used alternately for voice, record, or broadband data transmission. The last type of service has apparently been a major factor in military requirements. The Department of Defense has evidenced interest in broadband, rapid channels equivalent to 16 telephone voice channels. It is probable that a significant commercial demand for this type of service will not develop for a number of years. Data transmission over a large number of equivalent voice channels is required only for computers linked for simultaneous solution of problems. Where simultaneous solution is not required—the normal case—computers can be programmed to receive data over single voice channels.

The potential market for intercontinental television transmission has been the subject of much speculation. It appears unlikely, however, that television will become a major factor in overseas telecommunications for a number of years. Differences in time zones constitute a serious obstacle to simultaneous transmission of television programs to various areas. Even within the United States, these time differences make it necessary to transmit live first and by video tape later in order to attract a maximum audience. Overseas transmission would have to compete with video tapes, which can be flown cheaply and within a few hours between most continent. Since television transmission requires 600 equivalent voice channels, overseas transmission would be fairly expensive. If, for example, telecommunication channels could be leased for the low price of $50,000 per year, transmission of a one-hour program would cost at least $3,500. This is about ten times the cost of producing a video tape of the same program and flying it overseas. Live transmission to television between continents will probably be limited to showing events of widespread public interest such as coronations and other historic events and Olympic Games. It is primarily for such events that people would normally consider viewing during late night or early morning hours.

VI IMPACT OF THE PROPOSED NORTH ATLANTIC CABLE

A recent proposal that a 720-voice-channel transistorized cable be laid across the North Atlantic[12] has not been considered with respect to its impact on the potential market for satellite telecommunication services. Such a cable might be in service by the end of 1966. The impact on a satellite system would, of course, be on the revenues such a system might earn rather than on system costs. For a global satellite system, ground terminals along the Atlantic coasts of North America and Europe would, in any case, service traffic between Europe and Africa, Europe and South America, North America and Africa, and North America and South America. In addition, a satellite system might find limited use in carrying traffic over the North Atlantic during peak periods.

In assessing the impact of the proposed cable on satellite system revenues, it is of interest to examine the geographic distribution of overseas telephone calls. The estimates contained in Table II show that the North Atlantic route had by far the densest traffic during 1960. Of the 1,100 overseas circuits available in 1965 in deepwater cables over long routes, 476 circuits will be in cables crossing the North Atlantic. About 64 of the North Atlantic circuits may be leased by the military. The RAND Corporation study[7] concludes that by 1965 demand will be pressing hardest on circuit capacity on the North Atlantic route, and this view is confirmed by the proposal to place the first transistorized cable along this route. A communication satellite system could expect to derive about half of its revenues from North Atlantic traffic if the proposed cable is not installed. The revenue that a 720-channel cable might earn is estimated at $70 million which also represents the amount a satellite system might earn by about 1970 from North Atlantic traffic in the absence of such a cable.

Some analysts have suggested that a communication satellite system could evolve from an early regional system to a global system later. This has been based on the assumption that no deepwater cables would be laid after 1965, so that substantial revenues could be earned early from the North Atlantic traffic. It appears likely, however, that addition of the proposed cable in the North Atlantic would absorb most, if not all, the growth in revenues from that route through at least 1970 and possibly through 1972. The proposed early regional system would, therefore, be considerably less attractive commercially. The addition of the proposed cable would also extend the period during which a global communication satellite system can be expected to be unprofitable.

VII SYSTEM COSTS

The focus of this discussion of system costs is on a comparison between a medium-altitude, random-orbit satellite system and the synchronous satellite system. The unit costs as estimated in the RAND Corporation study[7] are close to the estimates in the Booz, Allen & Hamilton study.[3] Further refinement in these estimates is not possible at this time.

The variation in system cost estimates among the studies reviewed stems from the manner in which these costs are compiled and from different unit costs. Total system costs envisaged as a stream of annual expenditures are useful in deriving an estimate of when system revenues may exceed annual costs. This approach, which was used by J. W. A. Buyers[4], shows that a communication satellite system will require funding not only for initial investment but also for annual operating costs during the first years after the system commences operations. This conclusion holds even under the rather optimistic traffic forecasts made by that author; thus, the same conclusion would hold under the less optimistic traffic forecasts in this paper or the RAND Corporation study.

When comparing system costs for the purpose of choosing between competing systems, it is useful to emphasize only those elements that contributed to *differences* in system costs. For example, the costs of a central administrative staff for the Communication Satellite Corporation will be about the same whichever system is chosen. On the other hand, the research and development costs that the Corporation will have to bear are heavily dependent on the extent to which past research of both private industry and government agencies may be applicable to the specific problems of the Satellite Corporation. Be that as it may, the elements of the system whose costs will be estimated in the following discussion are limited to: communication satellites, ground stations, and the operations and maintenance costs associated with them.

Each system has certain cost advantages over the other. A random-orbit satellite costs considerably less than the more complex synchronous-orbit satellite. The costs estimated by the RAND Corporation were

$3.3 million per random-orbit satellite (a cost of $9.9 million per attempted launch with three satellites per launch vehicle) and $10.5 million per synchronous-orbit satellite (with one satellite per launch vehicle).[7] A larger number of random-orbit satellites would be required in orbit to provide a high percentage of in-service time—36 satellites for an inservice time of better than 99 percent. For a global system, synchronous-orbit satellites would be orbited in three stations—one each over the Atlantic, the Pacific, and the Indian Ocean. To insure continuous operation should a failure occur, more than one synchronous satellite would be placed in each station. The decision whether two satellites or three satellites should be orbited at each station involves an evaluation of reliability and the trade-off between risk of outages and costs of reducing that risk.

The number of satellites that will be launched depends on the number required in orbit, the lifetime of satellites in orbit (mean time between failures), and the satellite launch-success probability. The synchronous-orbit satellite system, which includes subsystems for position and attitude control and is thus more complex than a random-orbit system, can be expected to have a shorter mean time between failures (MTBF). The synchronous orbit places stricter requirements for guidance and control for launching than does a random orbit, so the probability of a successful launch can be expected to be lower for the synchronous-orbit satellite. For these reasons, the costs of placing and maintaining a given number of satellites in orbit can be expected to be spread wider than the cost per attempted launch indicates. Tabulated below are examples of estimated costs from the RAND report (pp. 43-44),[7] with the assumptions on which they are based:

SATELLITE SYSTEM	ASSUMPTIONS			15-YEAR LEVEL ANNUAL COST FOR PLACING AND MAINTAINING SATELLITES
	MTBF (years)	Launch Success Probability	No. Satellites in Orbit	
Random-Orbit	2	80%	36	$ 92.4 million
Synchronous-Orbit	1	50%	6 9	146.2 million 219.2 million

It is reasonable to assume that technological advances will lead to improvements in both the MTBF and the launch-success probability for both a random-orbit system and the synchronous-orbit system. The probable cost disadvantage during early technological stages of the synchronous-orbit system would be largely overcome, possibly even to the extent of giving the cost advantage to the synchronous-orbit system. Placing and maintaining 36 random satellites in orbit with MTBF of 5 years and the launch-success probability 90 percent would give 15 year level annual costs of about $40.3 million. For the synchronous system, with MTBF of 3 years and a launch-success probability of 80 percent, the 15-year level annual estimated costs would be $35.1 million for six satellites placed and maintained in orbit and $52.6 million for nine.

For a ground system consisting of terminal stations and a central data control and management center, estimated costs associated with the synchronous-orbit system are much lower than they are for a random-orbit system. The primary reason for this is the tracking requirements for a random-orbit system are more stringent. Terminal stations for a synchronous-orbit system would require fewer antennas than those for a random-orbit system, and the random-orbit system would also require rotating, mobile antennas which are much more expensive than the semi-mobile or stationary antennas required with the synchronous-orbit satellite system. A random-orbit system will also require equipment at the central data control and management center to swtich operations between satellites as they pass into and out of the horizons of the ground terminals, which the synchronous-orbit system will not require. The ground system for an early global network will comprise sixteen ground terminals plus a data control and management center. Since electronic equipment in these terminals has been estimated to have a lifetime of about 15 years, costs are expressed at 15-year level annual costs. These costs for the ground systems would be about $11.5 million with synchronous-orbit satellites and about $68.6 million with random-orbit satellites.

When the costs of satellites in orbit are added to the costs of their associated ground systems, the total cost of a random-orbit system appears favorable during early technological stages, which might be 1966 or 1967, particularly if an in-service time of slightly better than 98 percent is considered acceptable. Such an in-service time could be achieved by placing and maintaining 18 satellites in random orbit, which would imply satellite costs just half the amount necessary to achieve better than 99-percent in-service time with 36 satellites. With a later technology, however, the synchronous system would be clearly preferable from the viewpoint of estimated costs. The following estimates from the RAND report (pp. 44, 48)[7] illustrate this comparison:

SATELLITE SYSTEM	NO. SATELLITES IN ORBIT	15-YEAR LEVEL ANNUAL COSTS FOR SATELLITES AND GROUND SYSTEM (Millions of Dollars)	
		Early Technological Stages	Later Technological Stages
Random-Orbit	18 36	$115 161	$ 89 109
Synchronous-Orbit	6 9	158 231	47 64

Fifteen years, the period for which level annual costs were computed, is a long time in relation to the advances in booster and satellite technology. A significant improvement in system reliability (MTBF and launch-success probability) could be achieved in such a span of years, particularly with the back-up of a strong research and development program. Thus, the level annual costs given above are not truly representative of the probable costs for a 15-year span. Such probable costs would lie somewhere between those associated with the earlier technology and those associated with the later technology. How closely the costs for the later technology would be approached depends on the rapidity of technological advance. It is quite probable that during 15 years an early global network of terminal stations would expand toward a later network. Such a later network would include more terminal stations than would the earlier one, so that the relative cheapness of the synchronous-orbit ground system would have a greater impact on comparative total costs than the above estimates indicate.

In summation, it is reasonable to conclude that from the viewpoint of costs a random-orbit system appears favorable during early technological stages. With improvements in reliability, the real key to system costs, the synchronous-orbit system would be clearly favorable. Over a 15-year span, with advances in technology and probable increases in the number of terminal stations, there is a high probability that the synchronous-orbit system would cost less than a random-orbit system, despite the apparent advantage of a random-orbit system during early technological stages.

VIII AREAS FOR FURTHER RESEARCH

Any assessment of the economic aspects of communication satellites is highly dependent on a number of assumptions which must be made in the absence of reliable data and information. The chief assumptions are those made with regard to system reliability, which is plainly the critical factor determining system costs. All statements on system costs must be qualified by such assumptions.

Although this part of the report criticizes the uses made of economic indicators in forecasting telecommunication traffic and circuit requirements, this should not be taken to imply that all such efforts should be abandoned. The role of communications in economic growth and development is complex and cannot be accurately tied to single gross economic indicators. The techniques used by economists, including econometric model building, have often been of significant aid in explaining and projecting the growth in certain industries. The development of a reliable economic approach to forecasting overseas communication traffic will necessarily be long and difficult, and many avenues will be found to lead nowhere. Nevertheless, the task is an interesting and challenging one.

Many of the forecasts of equivalent voice channel requirements build from a forecast of message volume. A critical element in deriving channel requirements from traffic forecasts is the question of peak demand. The only information uncovered in this study is reproduced in Fig. 4, which shows the percentage of daily calls by hour going through the New York and White Plains terminals. This information indicates a 2:1 ratio of peak to average demand. The data, however, include calls across the Atlantic and to South America; it is not possible to peak loads for each of these two major divisions of traffic. Additionally, it is not known whether the data include traffic from one area to another via the United States. It is likely that the ratio of peak to average loads varies for different communication routes, since time zones cause a varying overlap of business hours among the major commercial centers of the world. The rules of thumb that a circuit is required for every 150 minutes

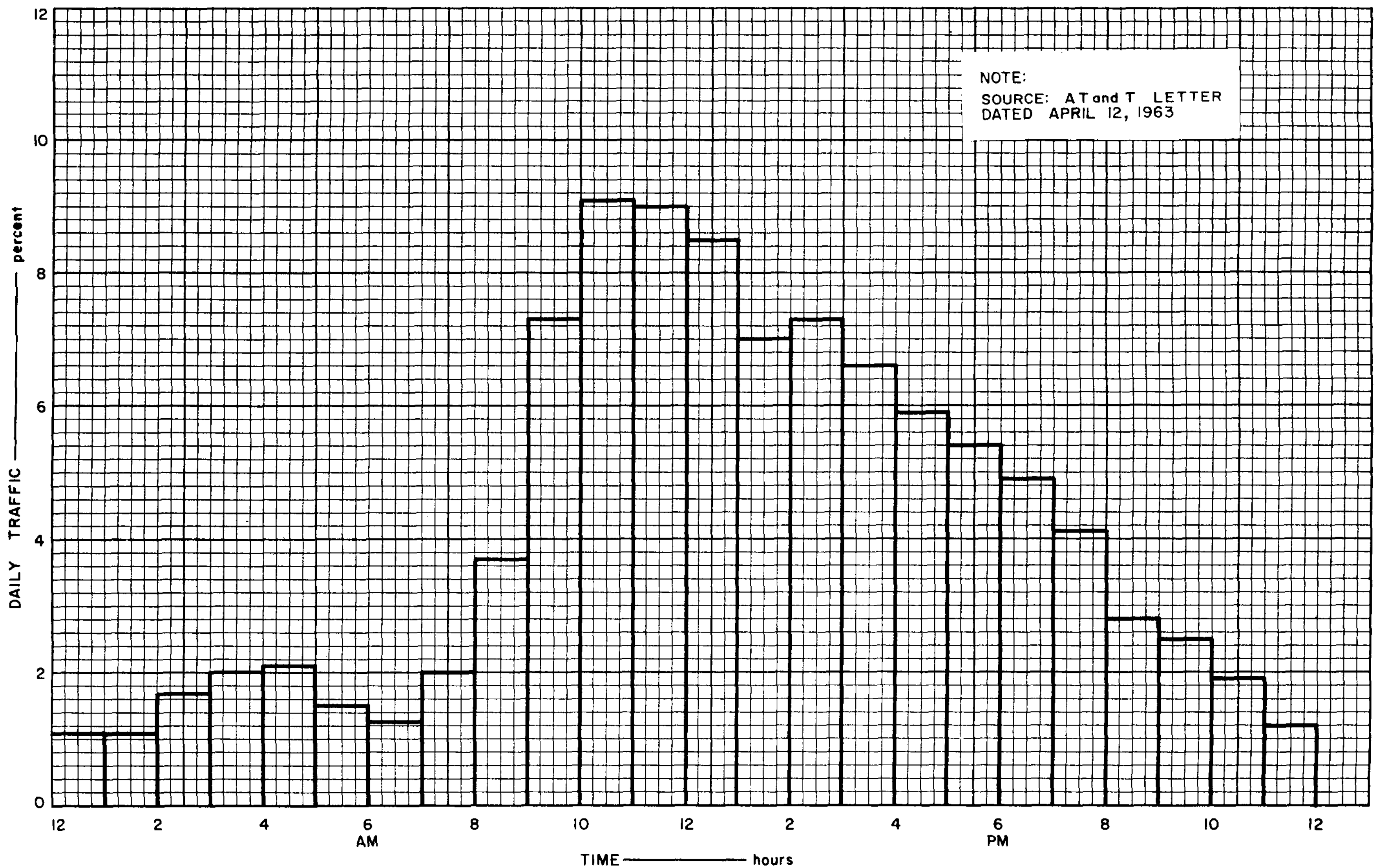

FIG. 4 DISTRIBUTION OF OVERSEAS CALLS THROUGHOUT THE DAY

of paid time and that peaks are twice the average load may lead to considerable inaccuracy in some forecasts. Additional research and data in this area would probably prove valuable.

An additional question on peaking is raised by statements that demand for communications is pressing on facilities for overseas telecommunications. If this is true, then the addition of significant capacity might result in an increase in peak-load-to-average-load ratios. Interpretations of recent data should be made with this possibility in mind, so that circuit requirements will not be understated through reliance on data that reflect an insufficient capacity to meet current demands.

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